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Short communication

The effect of music-induced emotion on visual-spatial learning in people with Parkinson's disease: A pilot study

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ABSTRACT

Introduction: Emotional states have been shown to influence cognitive processes including visual-spatial learning. Parkinson's Disease (PD), besides manifesting with the cardinal motor symptoms, presents cognitive and affective disturbances. Here we aimed at investigating whether manipulation of the emotional state by means of music was able to influence the performance of a visual-spatial learning task in a group of PD participants.
Methods: Ten PD patients and 11 healthy elderly (ELD) were asked to perform a visual-spatial learning task while listening two musical pieces evoking a neutral emotion or fear. Targets were presented on a screen in a preset order over four blocks and subjects were asked to learn the sequence order by attending to the display. At the end of each block, participants were asked to verbally recall the sequence and a score was assigned (Verbal Score, VS).
Results: Analysis of variance-type statistic test on the VS disclosed a significant effect of Music and sequence Blocks ($p = 0.01$ and $p < 0.001$, respectively) and a significant interaction between Group and sequence Blocks. Sequence learning occurred across the training period in both groups, but PD patients were slower than ELD and at the end of the training period learning performance was worse in PD with respect to ELD. In PD patients, like in ELD, fear-inducing music has a detrimental effect on visual-spatial learning performances, which are slower and decreased.
Conclusion: These findings confirm an impairment in visual-spatial learning in PD and indicates that the emotional state influences this learning ability similarly to healthy controls.

1. Introduction

The listening to music elicits emotions, and the improvement of the cognitive performance after the listening to music evoking positive emotions is widely known in literature. Since then, using several valid experimental protocols, a wide range of studies investigated the effect of music eliciting emotions and arousal on concurrent mental processing in healthy subjects and in patients with neurological diseases [1].

Visual-spatial learning requires coordinated activity with surroundings: individuals are required to use representations of the environment to comprehend and conceptualize visual representations and spatial relationships in learning. Emotions have been shown to influence this form of learning. Chan and colleagues [2] found that parahippocampal activity enhanced bilaterally when participants were engaged in an active object location memory task within a virtual house with rooms in which they had previously encountered negatively arousing events. Palmiero and colleagues [3], by using music to induce emotional states, showed that the persons after listening to positive music produce better scores at a visual-spatial learning task.

Parkinson's Disease (PD), beside manifesting with the cardinal motor symptoms, presents cognitive dysfunctions, including impairment in visual-spatial abilities, and affective disturbances. Interestingly,

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Marinelli and colleagues [4] showed that impaired performance at visual-spatial sequence learning in PD correlates with motor performance in a reaching task: patients with higher reaction times are the ones with a more impairment of visual-spatial sequence learning, suggesting that movement preparation shares resources with learning of visual-spatial sequences. Recently, we demonstrated that motor performance in PD is influenced by emotional processing: when patients with freezing of gait were asked to perform a step forward in response to unpleasant images inducing fear, the motor performance deteriorated, with increased reaction times [5]. A low performance at tasks implying the use of executive functions to perform movements under emotional contextual clues may imply a dysfunction of basal ganglia and of subcortical-cortical interaction. However, it is difficult to precisely localize which neural structure is pivotal in this dysfunction, given the behavioural nature of the tasks and the fact that PD is a network-based disorder.

Starting from all the above-mentioned observations, the aim of the present study was to investigate whether the manipulation of the emotional state by means of music was able to influence the performance of a visual-spatial learning task in a group of PD participants. In particular, we investigated the effect of fear-inducing music on visual-spatial learning since fear together with anxiety, is one of the most negative emotions experienced by PD patients [6] (e.g. fear of the future/falling/cognitive decline). However, while the negative effects of the anxiety on cognitive functions and quality of life are widely investigated [7], the impact of fear on cognitive performance is not yet well known. To this aim participants were asked to perform a visual-spatial learning task while listening two musical pieces evoking a neutral emotional state or fear.

2. Methods

2.1. Participants

A total of 21 participants (10 PD patients and 11 healthy elderly (ELD) gave their written informed consent to participate in this study. The study was approved by the regional ethics committee (n. 141/12). For PD subjects the inclusion criteria were: diagnosis of idiopathic PD (according to the United Kingdom Parkinson's Disease Society Brain Bank criteria) and Hoehn and Yahr stage ≤3. General exclusions criteria were: Mini Mental State Examination score <24, history of neurologic disorders (except PD), and visual, orthopaedic, or vestibular impairments that could hamper task performance. Executive and memory functions and affective status were evaluated by means of Tower of London test (TOL), Rey Auditory Verbal Learning Test (RAVLT), Beck Depression Inventory 2 (BDI-2), Apathy Evaluation Scale (AES). Fatigue and daytime sleepiness were evaluated with Fatigue Severity Scale (FSS) and the Pittsburgh Sleep Quality Index (PSQ-I) respectively. Only in PD participants, disease severity was evaluated with section III of the MDS–Unified Parkinson Disease Rating Scale.

2.2. Study design

In a repeated measures design (two separate sessions, one week

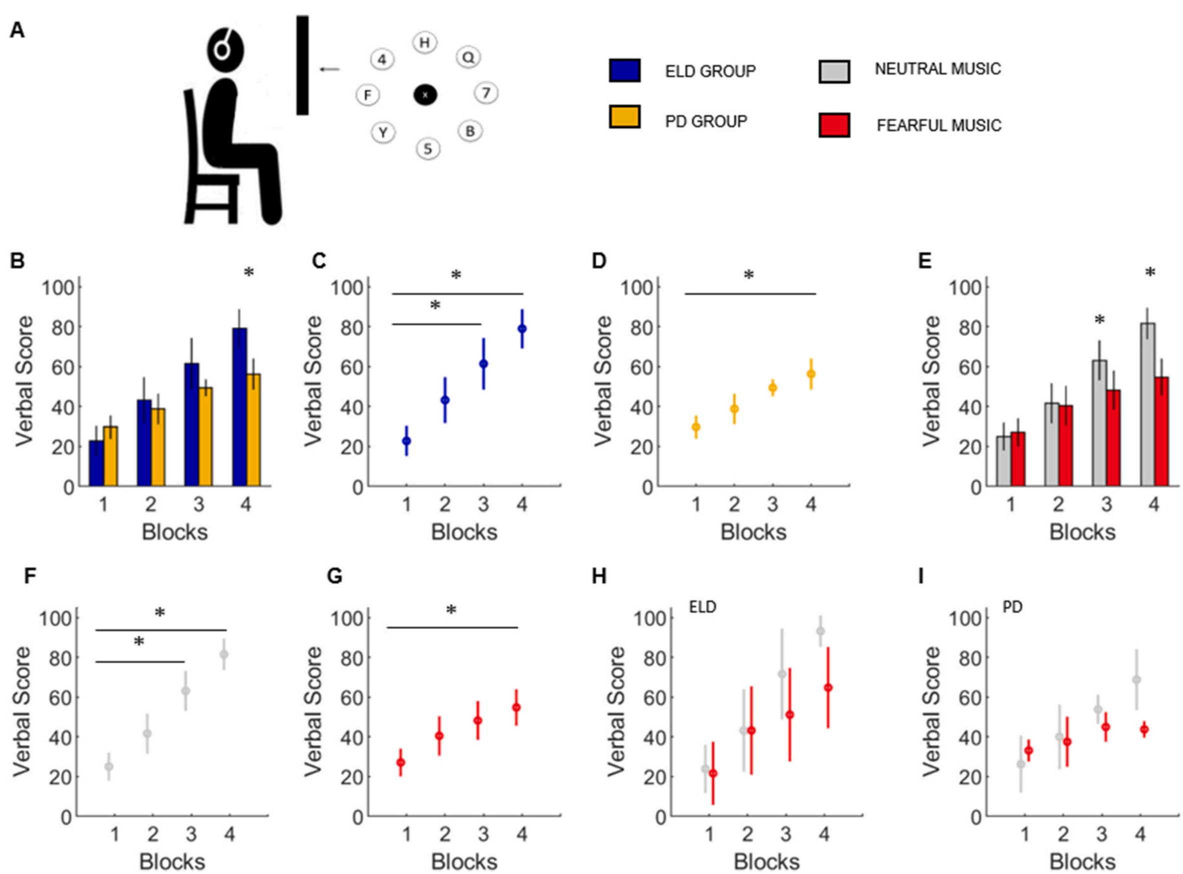

Fig. 1. A schematic representation of the experimental paradigm, where the subjects were seated in front of a screen and had to memorize the alphanumeric sequence shown, is reported in the panel A. The remaining panels report the Verbal Score attained by persons with Parkinson's Disease (PD) and Elderly (ELD) according to the interaction effect between-factor Group and the sequence Blocks (B, C, D), the interaction effect within-factor Music and the sequence blocks (E,F,G), and the interaction effect Group, Music and sequence Blocks (H,I). Circles/vertical bars and whiskers represent, respectively, the mean score and 95% confidence interval. * $P < 0.01$ post hoc test between PD vs ELD or Neutral vs Fearful Music at each sequence block (A,D). * $P < 0.01$ post hoc test between sequence blocks for each Group (ELD or PD, B and C) or Music (N or F, E and F).

apart), all participants were invited to learn two different alphanumeric sequences while listening two musical pieces evoking neutral or fearful emotions. The sequence and the music piece were randomly combined before starting the first session. During the visual-spatial learning task, subjects were sitting in front of the screen and were instructed to memorize an alphanumeric sequence displayed trough a set of 8 white circles placed on a circumference with a radius 10 cm at an interval of 45° from each other (Fig. 1A). Each target turned black for 700 ms, one at the time, according to a predetermined sequence with a time interval of 800 ms. Each session consisted of 5 blocks of trials: one familiarization block with 5 repetitions of 8 targets lighting up in a random order (40 trials) and four sequence blocks (S1, S2, S3, S4) with 4 repetitions of the predetermined sequence (128 trials). At the end of each session, participants were asked to verbally recall the alphanumeric sequence and a declarative score was assigned (Verbal Score, VS, expressed as %) ranging from 0 (unawareness-of-the-sequence) to 100 (complete-correct-sequence) [8]. We selected this task, without motor component, because engages visual-spatial attention and working memory [8,9] and it has been associated with EEG activity of the frontal and posterior parietal areas mostly in the right hemisphere [9]. This pattern likely reflects encoding of new information, access to memory storage and memory traces activation.

Regarding music, we chose two pieces able to evoke negative (fearful) and neutral emotions [10]. Participants listened to musical tracks with headphones while performing the learning sequence task only.

2.3. Statistical analysis

Group difference was assessed by Mann-Whitney-U Test for demographic and clinical characteristics and by Chi-square for gender. To test differences in VS across Group (PD vs ELD), Music (neutral vs fearful) and sequence Blocks a rank-based analysis of variance-type statistic (ATS) was. We used the F1-LD-F2 model, where Blocks and Music were the within-subject factors (repeated factors) and Group the between-subjects factor. In case of statistically significant differences (threshold of $p < 0.05$), Bonferroni-Holm post-hoc test for contrast analysis was applied.

In PD participants, the associations between VS and clinical variable (MDS-III), cognitive functions (TOL, RAVTL) and neurobehavioral features (BDI-2, AES, FSS and PSQ-I) were evaluated using Spearman correlation coefficients and the analysis was corrected for multiple comparisons using Bonferroni correction (0.05/2 = 0.025 for cognitive variables; 0.05/4 = 0.0125 for neurobehavioral variables). Marinelli et al. [4] have explored the visual-spatial learning between PD and ELD, reporting significant unpaired differences in the verbal score not normalized (mean(SD), PD 4.4(0.9) vs HS 7.1(0.7)). Hence given $\alpha = 1\%$ and $1\text{-}\beta = 95\%$, the minimum sample size per group is 5. Statistical analysis was performed using the nparLD package in R statistical software.

3. Results

Descriptive statistics for demographic and clinical data are reported in Table 1. Age, Sex and Education were comparable between groups ($p > 0.05$).

3.1. Visual-spatial sequence learning

Verbal score improved significantly across the training period (main effect Block $p < 0.001$). Statistical analysis also revealed a significant Block × Group interaction ($p = 0.03$, Fig. 1 B and C) and post-hoc analysis showed that VS improved significantly after two Blocks in ELD, whereas significant changes were detected in the last block in PD (ELD: S1vsS3, S1vsS4 $p < 0.01$, Fig. 1C; PD S1vsS4 $p < 0.01$, Fig. 1D). Also, post-hoc analysis revealed that VS was significantly higher in the ELD compared to PD at the end of the task (S4, ELD vs PD $p = 0.001$, Fig. 1B). A main effect of Music ($p = 0.01$, Fig. 1E) and a Block × Music interaction ($p = 0.001$, Fig. 1F and G) were also found. Post-hoc analysis showed that VS improved since the third block (S1vsS3 and S1vsS4 $p < 0.001$, Fig. 1F) when participants listened to neutral music, whereas significant changes were seen only at the last block when participant listening to fearful music (S1vsS4 $p < 0.001$, Fig. 1G). Post-hoc analysis also showed a significant difference in VS between music pieces from the third block (NvsF, S3 $p = 0.01$ S^4 $p < 0.001$). No significant Group X Music × Block interaction ($p = 0.99$, Fig. 1H and I) was detected.

Table 1
Demographic and clinical characteristics.

Number of participants	PD (n = 10)	ELD (n = 11)	
	median (IQR)	median (IQR)	P value
Age [year]	72.0 (69.0–75.0)	67.0 (62.5–71.0)	0.09
Sex	5 F / 5 M	5 M / 6 F	0.83
Education [year]	12.0 (6.0–13.0)	11.0 (8.0–13.0)	0.51
Disease duration [years]	11.0 (6.0–13.0)	-	-
MDS-UPDRS III [score]	23.5 (22–25)	-	-
H&Y stage	2 (2–2)	-	-
ToL [score]	27.0 (21.0–29.0)	32.0 (29.5–33.8)	0.01
RAVLT G [score]	29.0 (26.5–34.0)	33.0 (32.3–35.0)	0.02
RAVLT E [score]	31.1(28.8–34.5)	35.0(33.0–35.9)	0.05
BDI-2 [score]	7.5(3.0–11.0)	4.0(2.3–6.8)	0.17
AES [score]	16.0(13.0–20.0)	9.0(7.3–14.0)	0.08
FSS [score]	12.5(11.0–16.0)	2.0(1.3–3.0)	0.00
PSQI [score]	15.0(9.0–17.0)	8.0(3.3–9.0)	0.00

PD, Parkinson's Disease; ELD, Elderly, IQR, Interquartile Range; F, Female; M, male; MDS-UPDRS; Unified Parkinson Disease Rating Scale; TOL; Tower of London test; RAVLT, Rey Auditory Verbal Learning Test; BDI, Beck Depression Inventory 2; AES, Apathy Evaluation Scale; PSQI, Pittsburgh Sleep Quality Index; FSS, Fatigue Severity Scale.

3.2. Correlation analysis

Significant positive correlations were found between VS obtained after listening to neutral music and cognitive functions (RAVLT: $r = 0.600$ $p = 0.004$; TOL: $r = 0.564$ $p = 0.007$). Notably, these correlations disappeared when the VS obtained after listening to fear music was used for the analysis.

4. Discussion

In this study we tested declarative scores of visual-spatial sequence learning in healthy elderly and in PD patients. In particular, we explored whether it was possible to influence visual-spatial memory ability by using fearful music to manipulate emotional states.

The first result obtained is that the verbal score (VS), our primary outcome measure to test visual-spatial learning, improved significantly in both groups regardless of the type of emotional music. Improvements in declarative scores were seen at each block up to the end of the experimental session suggesting that both elderly and PD patients benefit from training, which is known to be a key element of motor learning process [4]. However, subjects with PD improved significantly only at the last block and at the end of the task, VS was lower compared to ELD. Indeed elderly learned about 80% of the sequence while PD patients about 60%. . The reduced learning in PD could reasonably be ascribed to cognitive disturbances associated with the disease. Indeed, in our sample of patients, differences on executive functions (i.e., ToL) and memory abilities (i.e., RAVLT) emerged in the assessment phase, where patients performed significantly worse than elderly.

Regarding the specific effect of music, we observed that listening to fearful music worsened visual-spatial learning performance in both groups. Thus, music-induced fear decreased the ability to store an alphanumeric sequence. Our results also showed no differences between PD patients and elderly regarding the effect of fearful music on visual-spatial learning. Although it is known that PD symptoms include also emotional aspects [5] and results on the ability to recognize music-induced emotions are still controversial [1], our finding are in accordance with previous data [1] showing that recognition of emotions from musical excerpts is still preserved.

The frontoparietal network is greatly involved in visual-spatial learning: it might be responsible for the active representation of attended and goal-relevant stimuli and thus for promoting adequate domain-dependent information processing [11]. Particularly, the dorsolateral prefrontal cortex (DLPFC) is likely engaged in maintaining working memory representations. Recent views suggest that neural regions traditionally being considered more involved in cognition, as the DLPFC, are not restricted to "cognition" processes; rather, their activity is modulated by "emotional" processes, indicating the interaction between cognition and emotion as a seamless function [12]. The DLPFC, although representing an abstract and higher-order goal representation, due to its lack of direct connectivity with sensory cortex and regions that represent affective value, is likely to receive affective information via the anterior cingulate in order to represent fear in the environment, influencing cognitive functions in relation to emotional states [13].

Interestingly, correlation analyses showed that, only when visual-spatial learning task was performed while listening the musical piece evoking neutral mood, the ability in the task correlated with cognition (verbal memory and executive functions) and not with neurobehavioral variables. However, this result may also be linked to the small sample size and has to be confirmed in a larger sample. Correlations between VS and cognitive scores disappeared when listening to the fearful music. One possible explanation is that the induced fear state exerts its effect on cognitive circuits underpinning visual-spatial ability making less prominent the contribution of individual cognitive and affective characteristics.

The study results show that in PD patients, like in ELD, fear-inducing music has a detrimental effect on visual-spatial learning. This finding indicates that the emotional state influences learning skills, suggesting the importance of carefully considering non-motor aspects of PD (anxiety/depression) when planning a rehabilitation program.

4.1. Limitations and future directions

This is a pilot study and a larger number of participants is needed to confirm our results. The visuo-spatial task adopted here, although been used in previous studies also for testing visuo-spatial abilities in PD [8,9] is not a clearly validated measure for testing this ability and this should be acknowledged as a limitation of the present study. Furthermore, we didn't measure the valence and arousal perceived by participants, useful to estimate the intensity of the emotional experience. Future studies should be planned to deeply investigate the effect of fear on cognitive performance, such as memory, in PD subjects. Finally, it could be interesting to also explore the effect of pleasure-evoking music on visual-spatial abilities, to gather more information useful for a tailored cognitive rehabilitation aimed at improving this performance.

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Data

Data supporting these findings are available from the corresponding author upon reasonable request.

Financial disclosures

None.

Declaration of competing interest

None

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